AIAA 81-4199

Retardation System for Relatively Low-Altitude, High-Subsonic Speed, 2000-lb Payload Deliveries

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Introduction

TRADITIONALLY, high-speed retarded delivery, particularly of shock-sensitive payloads, has been accomplished by means of two-stage parachute systems. The first stage normally consists of a heavily constructed ribbon-type parachute, designed to survive high dynamic pressure and to slow the payload to a velocity that a second-stage parachute can survive in order to further slow the payload to an acceptably low impact velocity.

Two-stage lifting parachute systems have also been developed, primarily for very-low-altitude, subsonic and transonic deliveries. These systems decrease the impact energy of a payload to about one-tenth that of previously heavily constructed one-stage parachute systems used for this purpose. In addition, lifting parachute systems increase the impact angle to nearly vertical, a feature not achievable with conventional one- or two-stage parachute systems.

Objective

In 1977, a one-stage parachute system was proposed as an inexpensive but effective means of achieving relatively low-altitude, high-subsonic delivery of a payload weighing approximately 2000 lb. To reduce the probability of ricochet greater than 400 ft, the system had to be capable of demonstrating a nonshallow impact angle at a not-too-severe impact velocity. In addition, the system had to meet the constraints of limited parachute weight and volume, as well as be economically attractive in production lot quantities of 3000 systems per year.

Furthermore, the conceptual, validation, and full-scale development phases (including laboratory and operational field testing prior to production) were to be completed in less than 1 yr.

Technical Approach

On the basis of laboratory tests and analyses during the conceptual and validation phases, a one-stage, cross-parachute system was selected in order to meet the operational requirements and the added constraints of low cost and timely availability.

The parachute design (Fig. 1) provided an effective area of 53 ft^2 and a packaged volume of approximately 0.9 ft^3. Initiation of parachute deployment was established at no less than 1.0 s after aircraft release in order to satisfy aircraft clearance (safety) requirements.

A two-stage parachute system was ruled out for three reasons: insufficient time of flight at low-altitude delivery to deploy a second parachute prior to impact, no requirement for parachute opening shock control, and too costly to produce. Lifting parachute systems were considered, but also ruled out because roll control (an added cost factor) would be necessary to assure acceptable impact conditions and minimize dispersion.

Full-Scale Testing

During September/October 1978, 34 full-scale development field tests were conducted with notable success at release velocities of less than 450 knots indicated air speed (kias). Full inflation of the parachute occurred approximately 1.4 s after payload release with impact occurring less than 3.0 s later.

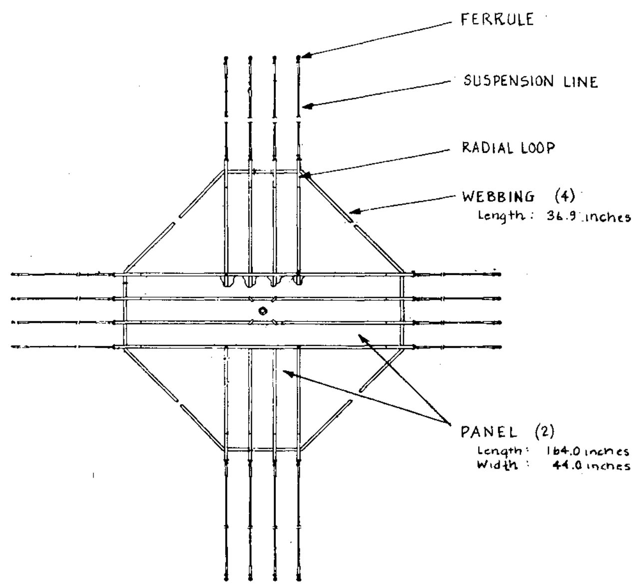

Fig. 1 Cross-parachute characteristics and dimensions.

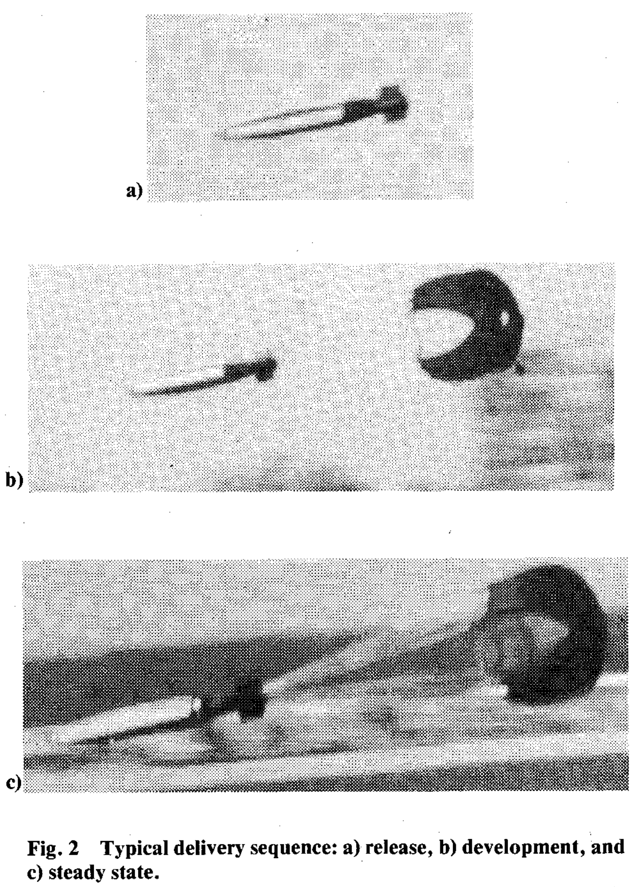

Fig. 2 Typical delivery sequence: a) release, b) development, and c) steady state.

Received Nov. 18, 1980.

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Table 1 Summary of representative air drops conducted in September/October 1978 and May/June 1979 (2000 lb payload)

Date	Release Velocity, kias	Release Altitude, ft	Parachute deployment Cover off, s	Parachute deployment Line stretch, s	Parachute deployment Full inflation, s	Payload Impact, s	Payload Impact angle, deg	Payload Impact velocity, ft/s	Payload Ricochet, ft
14 Sep 78	500	225	1.10	1.31	1.48	3.80	15	301	0
14 Sep 78	500	205	1.15	1.34	1.50	3.86	14	295	60
20 Oct 78	510	140	1.08	1.27	1.40	2.93	8	443	1365
27 Oct 78	500	150		No retardation		2.53	10	833	0
30 Oct 78	500	170	1.06	1.26	1.42	3.09	9	323	800
30 Oct 78	500	170	1.02	1.23	1.35	3.00	12	609	0
25 May 79	507	145	1.03	1.25	1.34	3.24	9	370	75
25 May 79	525	216	1.05	1.25	1.35	4.34	14	233	65
30 May 79	501	166	1.04	1.26	1.36	3.37	11	319	680
12 Jun 79	501	254	1.19	1.42	1.51	4.62	14	258	0
13 Jun 79	485	265	1.17	1.38	1.49	4.97	19	296	0
14 Jun 79	497	241	1.17	1.39	1.49	4.60	16	243	275
14 Jun 79	504	234	1.12	1.34	1.44	4.55	16	165[a]	0
14 Jun 79	503	230	1.10	1.33	1.42	4.66	18	253	280
14 Jun 79	510	254	1.20	1.43	1.52[a]	4.51	18	265	0

[a] Questionable data points.

Impact times, impact angles, and impact velocities, as expected, varied according to the initial release conditions (velocity and altitude). Figure 2 shows a typical delivery sequence.

Although there were no parachute failures at release velocities below 450 kias, parachute failures did occur at release velocities of 450-525 kias. Four parachutes failed because suspension lines broke, and three parachutes failed because canopies either tore or squidded.

Subsequent to these tests, improvements were made to correct the deficiencies experienced at high release velocities. Principally, the parachute material was changed to increase the critical velocity threshold.

In May/June 1979, 31 additional full-scale development tests were conducted. During the second test of this series at a 480 kias release velocity, the top of the parachute canopy was torn after it was struck by the metal cover plate used to deploy the parachute. To correct this problem, two drag-producing banners were attached to the cover plate. However, on the fourth test at 525 kias, the suspension lines to the top panel of the parachute failed. This failure, coupled with the ineffectiveness of the drag banners, resulted in several more design changes:

1) Use of the cover plate to deploy a small extraction parachute after which the cover plate falls free of the parachute.

2) Specification of a minimum breaking strength of 4900 lb of the parachute suspension lines.

3) Protection of the suspension lines with nylon sleeves in the area of contact with the metal parachute housing.

4) Use of Teflon tape to cover the rivets and weld areas inside the parachute housing.

After a number of successful tests (following the design changes) at release velocities as high as 520 kias, a suspension line failed unexpected in the top panel of a parachute at 451 kias. The cause of this failure was attributed to a stress concentration in the splice area of two suspension lines equipped with a wire pull system. A single-wire pull system with a lower stress concentration was then incorporated in the remaining parachutes. This modification constituted the last design change. In all subsequent tests, the parachutes when deployed functioned as intended at release velocities of approximately 500 kias and altitudes ranging between approximately 145 and 265 ft. The results of a representative number of tests conducted in September/October 1978 and May/June 1979 are summarized in Table 1.

Future Plans

Refinement of the cross-parachute system is continuing with additional testing scheduled for July/August 1981 using production units.

Conclusions

Before this program was undertaken, a data base had already been established for the design of high-speed ribbon parachutes by a careful analysis of many ribbon parachutes tested at high-subsonic and supersonic release velocities. This data base, combined with an understanding of the factors governing critical velocity, provides assurance that ribbon parachute designs do not approach critical opening velocities or result in suspension line failures.

However, an equivalent data base did not exist for cross parachutes. This is not to imply that a cross parachute should not have been selected for use in the high-subsonic release velocity range with heavy payload since the cross parachute has obvious advantages in cost, weight, and volume that makes its use highly desirable. What is does imply is that this program had to establish the fundamentals of a cross-parachute data base concurrently with the development of a capability to deliver a heavy payload using a cross parachute.

Accordingly, this first cross-parachute application in the 500+ kias release velocity range with a payload weighing 2000 lb was approached with the understanding that the limited theoretical analyses had to be supplemented with tests on a sufficiently broad basis.

The tests completed to date have demonstrated that the cross-parachute design is below the critical opening velocity threshold and that the suspension lines are of sufficient strength and are adequately protected for the intended application; that is, for delivery of a 2000 lb payload at high-subsonic release velocity and relatively low altitude.

Acknowledgments

The accomplishments to date have been achieved by the Naval Surface Weapons Center with invaluable field testing support provided by the National Parachute Test Range and the Naval Air Development Center. The program is under the direction of the Naval Sea Systems Command.